

REMARKS

This Preliminary Amendment amends the originally-filed Abstract of the above-referenced U.S. application, and provides the amended Abstract on a separate sheet. In addition, the Preliminary Amendment amends the originally-filed specification of the above-referenced U.S. application, via a substitute specification, to refer to and claim priority from the underlying PCT Application No. PCT/JP2004/008152 which was filed on [REDACTED] which was filed on June 4, 2004 and published on December 15, 2004 as International Publication No. WO 2004/108312, and from Japanese Patent Application No. 2003-162490, filed June 6, 2003, pursuant to 37 C.F.R. § 1.78(a)(2). In addition, the specification has been amended to reflect the changes to the specification implemented pursuant to PCT Article 34 and to remove minor informalities from originally-filed application. A marked-up comparison documents between the originally-filed specification and the substitute specification is enclosed herewith.

Further, originally-filed claims 1 and 2 of the underlying PCT Application No. PCT/JP2004/008152 have been cancelled, without prejudice, and new claims 3 and 4 have been added to provide the originally-filed claims 1 and 2 in an appropriate form for prosecution before the U.S. Patent and Trademark Office, and not due to any reason of patentability. Accordingly, claims 3 and 4 are now under consideration in the above-identified application. The amendments to the specification and new claims do not add new matter to the application.

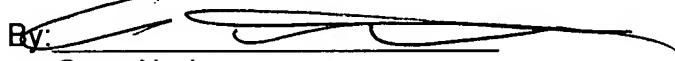
The underlying PCT Application No. PCT/JP2004/008152 includes an International Search Report, dated September 23, 2004, a copy of which is included. The Search Report includes a list of document(s) that have been considered by the Examiner in the underlying PCT application.

Enclosed herewith, please also find a copy of the PCT Written Opinion for the underlying PCT Application No. PCT/JP2004/008152, also dated September 23, 2004, and PCT Preliminary Examination Report therefor dated December 27, 2004. Applicant notes that both the PCT Written Opinion and the PCT Preliminary Examination Report confirm that the pending claims 1 and 2 comply with the requirements set forth in PCT Article 33(2)-(4).

Applicant asserts that the present invention is new, non-obvious, and useful. Prompt consideration and allowance of the pending claims are respectfully requested.

Respectfully submitted,

Dated: December 6, 2005

By:   
Gary Abelev  
Reg. No. 40,479

Attorney(s) for Applicant(s)  
DORSEY & WHITNEY LLP  
250 Park Avenue  
New York, New York 10177  
(212) 415-9200

4820-4157-7984\1

## VOSSIUS &amp; PARTNER

Vossius &amp; Partner POB 86 07 67 81634 Munich Germany

European Patent Office  
Erhardtstr. 27

80298 MÜNCHEN

PATENTANWÄLTE  
EUROPEAN PATENT ATTORNEYS  
EUROPEAN TRADEMARK ATTORNEYS

Dr. VOLKER VOSSIUS, Dipl.-Chem.  
(bis 1992; danach in anderer Kanzlei)  
Dr. PAUL TAUCHNER, Dipl.-Chem.  
Dr. DIETER HEUNEMANN, Dipl.-Phys.  
Dr. PETER A. RAUH, Dipl.-Chem.  
Dr. GERHARD HERMANN, Dipl.-Phys.  
JOSEF SCHMIDT, Dipl.-Ing.  
Dr. HANS-RAINER JAENICHEN, Dipl.-Biol.  
Dr. ALEXA VON UEXKÜLL, M.Sc.  
Dr. RUDOLF WEINBERGER, Dipl.-Chem.  
AXEL STELLBRINK, Dipl.-Ing.  
Dr. JOACHIM WACHENFELD, (Biol.)  
Dr. FRIEDERIKE STOLZENBURG, Dipl.-Biol.  
RAINER VIKTOR, Dipl.-Ing.  
Dr. NATALIA BERRYMAN, Dipl.-Chem.  
Dr. JÜRGEN MEIER, Dipl.-Biol.

## EUROPEAN PATENT ATTORNEYS

Dr. RENATE BARTH, Dipl.-Chem.  
Dr. URSULA ENGLBRECHT, Dipl.-Chem.  
Dr. PETER EINMAYR, Dipl.-Chem.

## RECHTSANWÄLTE

HELGA TREMMEL  
Dr. JOHANN PITZ  
BARBARA GUGGENMOS, Dipl.-Chem.  
Dr. THURE SCHUBERT  
SIMONE SCHÄFER  
JENNIFER CLAYTON-CHEN

Partnerschaftsregister Amtsgericht München PR 89

PCT/JP2004/008152

Nippon Steel Corporation  
Our Ref.: K 2271 PCT

Copy

December 10, 2004  
BE/RWA

## 1. Amendments

The expression “1 m<sup>3</sup>” on page 7, line 23 has been replaced by “1 m<sup>2</sup>”. The replacement is based on the description from the bottom line on page 9 to the top line on page 10.

The expression “1 m<sup>3</sup>” in claim 2 has been replaced by “1 cm<sup>3</sup>”. The replacement is based on the description from line 28 on page 15 to line 4 on page 16.

## 2. Requests

It is requested that prosecution be based on the application as filed including the two above-mentioned amendments.

*Natalia Berryman*  
Dr. Natalia Berryman  
European Patent Attorney

## Enclosures

Amended page 7 of the description (+ copy with handwritten amendments)  
Amended claims set (+ copy with handwritten amendments)

VISITING ADDRESS:  
Siebertstrasse 3  
81675 Munich  
Germany

POSTAL ADDRESS:  
POB 86 07 67  
81634 Munich  
Germany

TEL.: +49-89-41 30 40  
FAX: +49-89-41 30 41 11  
+49-89-41 30 44 00 (Trademarks)  
EMAIL: info@vossiusandpartner.com  
WEBSITE: www.vossiusandpartner.com

any fire accident, when a lubricating oil which is added with one kind or two or more kinds among high-basic alkaline-earth metal phenate, high-basic alkaline-earth metal carboxylate, high-basic alkaline-earth metal salicylate, high-basic alkaline-earth metal sulfonate, and the like, is supplied by a gas atomizing method.

After dedicated examinations to solve the problems, the inventor discovered that it is possible to perform a safe and stable lubricated hot rolling while preventing fire from occurring even if a lubricating oil is supplied by the gas atomizing method in which the aforesaid high-basic alkaline-earth metal compound of relatively high viscosity is blended, with the following conditions:

- (1) the average particulate size of the lubricating oil is made to be less than 1 mm,
- (2) the flow rate of the noncombustible gas (for example, air, helium, nitrogen, argon, or the like) sprayed concurrently with the lubricating oil in a form of particulates is made to be 2000 cm<sup>3</sup> or more per minute,
- (3) the spraying speed of the gas is made to be 1 m or more per second, and
- (4) the maximum amount of lubrication supply is made to be 20 cm<sup>3</sup> or less per 1 m<sup>2</sup> of the roll surface area.

In order to prevent fire caused by the lubricating oil, for example, scattering of the lubricating oil sprayed from the nozzle to areas other than the rolls should be prevented as much as possible, and 100% of the lubricating oil sprayed from the nozzle should adhere to the roll surface. This is because that when the lubricating oil

CLAIMS

10. Dez. 2004

What is claimed is:

1. A lubricated hot rolling method,  
using a lubricating oil which contains one kind or two  
or more kinds among an high-basic alkaline-earth metal  
phenate, high-basic alkaline-earth metal carboxylate, high-  
basic alkaline-earth salicylate, or high-basic alkaline-  
earth metal sulfonate having a basicity of 40 mgKOH/g or  
higher, and has a viscosity at 40°C of 800 cSt or less, said  
lubricated hot rolling method comprising the step of:

supplying, when a material to be rolled is supplied  
between two rolls, said lubricating oil to said rolls, by  
using a noncombustible gas whose flow rate for one  
lubricating nozzle is 2000 cm<sup>3</sup> or higher per minute, and  
whose flow velocity is 1 m per second or higher, in 0.01 cm<sup>3</sup>  
or more and 20 cm<sup>3</sup> or less per 1 m<sup>2</sup> of surface area of said  
rolls, after said lubricating oil is granulated or atomized  
into particulates having an average size of 1 mm or smaller.

2. The lubricated hot rolling method according to  
claim 1, wherein

the supply of said lubricating oil is started before  
said material to be rolled is bit between said two rolls,  
and an amount supplied of said lubricating oil is 1 cm<sup>3</sup> or  
smaller per 1 m<sup>2</sup> of surface area of said rolls.

any fire accident, when a lubricating oil which is added with one kind or two or more kinds among high-basic alkaline-earth metal phenate, high-basic alkaline-earth metal carboxylate, high-basic alkaline-earth metal salicylate, high-basic alkaline-earth metal sulfonate, and the like, is supplied by a gas atomizing method.

After dedicated examinations to solve the problems, the inventor discovered that it is possible to perform a safe and stable lubricated hot rolling while preventing fire from occurring even if a lubricating oil is supplied by the gas atomizing method in which the aforesaid high-basic alkaline-earth metal compound of relatively high viscosity is blended, with the following conditions:

- (1) the average particulate size of the lubricating oil is made to be less than 1 mm,
- (2) the flow rate of the noncombustible gas (for example, air, helium, nitrogen, argon, or the like) sprayed concurrently with the lubricating oil in a form of particulates is made to be 2000 cm<sup>3</sup> or more per minute,
- (3) the spraying speed of the gas is made to be 1 m or more per second, and
- (4) the maximum amount of lubrication supply is made to be 20 cm<sup>3</sup> or less per 1 m<sup>2</sup> of the roll surface area. X

In order to prevent fire caused by the lubricating oil, for example, scattering of the lubricating oil sprayed from the nozzle to areas other than the rolls should be prevented as much as possible, and 100% of the lubricating oil sprayed from the nozzle should adhere to the roll surface. This is because that when the lubricating oil

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 Nippon Steel Corporation  
 Our Ref.: K 2271 PCT

CLAIMS

VOSSIUS & PARTNER  
 PATENTANWÄLTE  
 SIEBERTSTR. 4  
 81675 MÜNCHEN  
 10. Dez. 2004

## REVISED PAGES

( Handwritten Amendments )

What is claimed is:

1. A lubricated hot rolling method,  
 using a lubricating oil which contains one kind or two  
 or more kinds among an high-basic alkaline-earth metal  
 phenate, high-basic alkaline-earth metal carboxylate, high-  
 basic alkaline-earth salicylate, or high-basic alkaline-  
 earth metal sulfonate having a basicity of 40 mgKOH/g or  
 higher, and has a viscosity at 40°C of 800 cSt or less, said  
 lubricated hot rolling method comprising the step of:

supplying, when a material to be rolled is supplied  
 between two rolls, said lubricating oil to said rolls, by  
 using a noncombustible gas whose flow rate for one  
 lubricating nozzle is 2000 cm<sup>3</sup> or higher per minute, and  
 whose flow velocity is 1 m per second or higher, in 0.01 cm<sup>3</sup>  
 or more and 20 cm<sup>3</sup> or less per 1 m<sup>2</sup> of surface area of said  
 rolls, after said lubricating oil is granulated or atomized  
 into particulates having an average size of 1 mm or smaller.

2. The lubricated hot rolling method according to  
 claim 1, wherein

the supply of said lubricating oil is started before  
 said material to be rolled is bit between said two rolls,  
 and an amount supplied of said lubricating oil is 1 cm<sup>3</sup> or  
 smaller per 1 m<sup>2</sup> of surface area of said rolls. X

DESCRIPTION In the United States Patent and  
Trademark Office

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Date of Deposit: December 6, 2005

I hereby certify that the document is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above and is addressed to Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

Gary Abeley, Esq.

(Name)

Signature

DORSEY & WHITNEY, L.L.P.

250 PARK AVENUE

NEW YORK, NEW YORK 10177

TO ALL WHOM IT MAY CONCERN:

Be it known that I, TSUYOSHI INOUE, a citizen of Japan, whose post office address is c/o NIPPON STEEL CORPORATION, Technical Development Bureau, 20-1, Shintomi, Futtsu-shi, Chiba 293-8511, JAPAN, has invented an improvement in

**LUBRICATED HOT ROLLING METHOD**

Cross Reference To Related Application(s)

[0001] This application is a national stage application of PCT Application No. PCT/JP2004/008152 which was filed on June 4, 2004 and published on December 15, 2004 as International Publication No. WO 2004/108312 (the "International Application"), the entire disclosure of which is incorporated herein by reference. This application claims priority from the International Application pursuant to 35 U.S.C. § 365. The present application also claims priority under 35 U.S.C. § 119 from Japanese Patent Application No. 2003-162490, filed June 6, 2003, the entire disclosure of which is incorporated herein by reference.

Technical Field of the Invention

[0002] The present invention generally relates to a hot rolling method using a lubricating oil in a hot rolling step of a steel manufacturing process. TheIn particular, the present inventionspecifically relates to a method to safely perform lubricated rolling by preventing fire accident which is likely tocan occur by exposing a lubricant oil to a hot air atmosphere, in a lubricated hot rolling method using a lubricating oil containing an high-basic alkaline-earth metal compound, where rolling ismay be performed in a manner that the lubricating oil is granulated to particulates, blown out not necessarily by

using water—but, and instead by a noncombustible gas, and provided to rolls adherently.

#### Background ArtInformation

5 [0003] There are~~may~~ be various objects to perform the lubricated hot rolling, such as to lower frictional force during rolling, and thereby reducing roll abrasion so that an energy-saving effect is attained; to enhance the quality of the produce surface; and so forth. Drawing particular attention in these 10 days is~~For example,~~ a technique to control, (by supplying a lubricating oil, a surface damage of an HSS roll (e.g., high speed steel roll), which has become pervasive as a roll material for hot rolling. Patent Documents 1, 2, 8, and 9 disclose~~For example,~~ Japanese Patent Application Laid-open Nos. Hei 05-15 306397, 08-188789, 6-79330 and 7-3279 describe that when a lubricating oil containing an high-basic alkaline-earth metal phenate, an high-basic alkaline-earth metal carboxylate, an high-basic alkaline-earth metal salicylate, an high-basic alkaline-earth metal sulfonate, or the like whose basicities are 20 40 mgKOH/g or greater, iscan be emulsified by applying a water injection supplying method (e.g., may be presently prevailing method) to perform hot rolling, a sticking-prevention effect ismay be enhanced, and a controlling effect of peeling of the

oxide film (mill scale) on the surface of the HSS roll regarded as a cause of rough surface ~~is~~can be attained.

[0004] Furthermore, in the hot rolling, a plate is thicker than in cold rolling, and a feeding device of a material ~~is~~may not be provided, so that bit slippage and rolling slippage ~~are~~may likely to occur. There are some known techniques to solve this problem. ~~The most well~~For example, it is known is to operate by reducing the amount supplied of the lubricating oil when the operation is carried out under such conditions that ~~will~~can obtain a lubricating effect within a range of not causing a slippage accident. ~~Other than that, there is a~~A known method can be utilized in which the lubricated rolling is not performed before and after the top portion of a rolled material is bit into a rolling mill and the bottom portion thereof comes off the rolling mill, so that bit slippage is prevented. On the other hand, ~~Patent Document 3 discloses~~Japanese Patent Application Laid-open No. Hei 06-234989 describes a technique ~~using~~which uses a lubricant whose self-friction coefficient is high so that bit slippage and the like do not occur even if the lubricated rolling is performed to the top and bottom portions of the steel.

[0005] ~~Non-patent Document 1~~"Theory and Practice of Flat Rolling", p. 218, The Iron and Steel Institute of Japan describes, (as a lubrication supply method in hot rolling, a

method in which a lubricating oil and vapor are blended and supplied in a spraying manner, other than the aforementioned method in which water and a lubricating oil are blended and supplied in a spraying manner in an emulsified form. On the 5 other hand, Patent Documents 4, 5 and 6 disclose, Japanese Patent Application Laid-open Nos. Hei 11-279656, 11-279657 and 11-293345 describe (as a manufacturing method of hot rolling steel for deep drawing which is superior in uniformity of plate thickness) a technique outlined as that the amount supplied of 10 a lubricating oil is 0.2 to 10 cm<sup>3</sup> per 1 m<sup>2</sup> of a surface area of the roll.

[0006] Further, Patent Document 7 discloses, Further, Japanese Patent Application Laid-open No. 2003-94104 describes (as a lubricating oil supplying method not using water) a 15 method to sprayedly supply to rolls the lubricating oil atomized or granulated to particulates using noncombustible gas, together with noncombustible gas, the. The supplying method can be known for: (i) providing a substantial friction-coefficient-reducing effect with a little amount supplied of the lubricating oil, 20 (ii) reducing the friction force to the rolls, which reduces the roll abrasion, resulting in an effect of prolonging the life of the rolls; and (iii) providing a good resistance to disturbance since spraying of the noncombustible gas with the lubricating oil to the rolls allows the lubricating oil to reach the surface

of the roll by blowing off the water film even if such water film formed by insufficient drying off of the roll cooling water exists on the surface of the roll.

[00071] When a lubricating oil being added with one kind

5 or two or more kinds among the high-basic alkaline-earth metal phenate, high-basic alkaline-earth metal carboxylate, high-basic alkaline-earth metal salicylate, high-basic alkaline-earth metal sulfonate, and so forth, is used as an emulsified lubricant by being blended with water, the viscosity thereof ~~is~~may be higher  
10 than with conventional lubricating oils, so that nozzle clogging or pipe clogging is likely to occur. Accordingly, frequent cleaning of the pipe and nozzle ~~is~~may be required, which ~~is~~  
~~leading~~can lead to a deterioration of manufacturing efficiency. Further, in the case of ~~using~~the use of the emulsion-lubricated  
15 method, a dry-off wiper ~~is~~can be provided between a roll cooling water supplying section and a lubrication supplying section in order not to wet the lubrication supplying section with the roll cooling water. However, when the roll cooling water leaks into the lubrication supplying section through a clearance made by  
20 the rotation of the rolls and abrasion of the wiper, the lubricating oil supplied in the form of emulsified lubrication ~~becomes~~may become not easily adherable to the rolls. This ~~occurs~~can occur because the roll cooling water that leaks forms a water film over the surface of the roll, and further, the

emulsion is blended with the cooling water so that its concentration (amount of the lubricating oil to water) is reduced, and the lubricating effect becomes difficult to be obtained. It is known that the same problem occurs with a 5 supplying method in a steam-atomizing form. The concentration of the emulsified lubricant which is practically used is generally about 0.5 to 1.0 of lubricating oil to 100 of water in terms of ratio by weight. This range represents a range in which the slippage-accident prevention and the lubricating 10 effect coexist. However, the concentration is constantly changing by the dirt within the lubricant piping system, clogging of the nozzle, and further, a slight difference of viscosity of the lubricating oil by changing of temperature and 15 humidity. A consequent problem that variation of lubricating effect occurs is also recognized.

[00081] It is known that approximately the same problem occurs with a supplying method in a steam-atomizing form. The concentration of the emulsified lubricant which is practically used is generally about 0.5 to 1.0 of lubricating oil to 100 of 20 water in terms of ratio by weight. This range represents a range in which the slippage-accident prevention and the lubricating effect coexist. However, the concentration may be constantly changing by the dirt within the lubricant piping system, clogging of the nozzle, and further, a slight difference

of viscosity of the lubricating oil by changing of temperature and humidity. A consequent problem that variation of lubricating effect occurs may also be recognized.

[0009] In order to solve these problems, if the method

5 discloseddescribed in Japanese Patent Document 7Application Laid-open No. 2003-94104 is used, in which the lubricating oil is granulated into particulates and sprayed with the noncombustible gas to the rolls without using any water (hereinafter referred to as a gas atomizing method), a supply 10 device with a very simple piping system can be formed, allowing.

15 This may allow many of the above-described problems to be solved, and providing a firm resistance to external variable factors (such as, e.g., a seasonal change in viscosity or change in humidity, for example). However, in this method, the lubricating oil itself is can be directly supplied to the rolls near a steel material heated to approximately  $800^{\circ}\text{C}$  to  $1200^{\circ}\text{C}$ , so that depending on the physicality and the usage environment of the lubricating oil, fire may break out in some instances.

20 In particular, a lubricating oil being added with one kind or two or more kinds among the high-basic alkaline-earth metal phenate, high-basic alkaline-earth metal carboxylate, high-basic alkaline-earth salicylate, high-basic alkaline-earth metal sulfonate, and the like has a higher viscosity than lubricating oils not being added with them, so that when the lubricating oil

is supplied in a manner ~~disclosed~~described in Japanese Patent Document 7, Application Laid-open No. 2003-94104, it is likely to scatter to or be deposited over the rolling mill facilities other than the rolls, causing a problem that the deposit flashes 5 and sets a fire.

[0010]

[0011] Patent Document 1

[0012] Japanese Patent Application Laid-open No. Hei 05-306397

10 [0013] Patent Document 2

[0014] Japanese Patent Application Laid-open No. Hei 08-188789

[0015] Patent Document 3

15 [0016] Japanese Patent Application Laid-open No. Hei 06-234989

[0017] Patent Document 4

[0018] Japanese Patent Application Laid-open No. Hei 11-279656

[0019] Patent Document 5

20 [0020] Japanese Patent Application Laid-open No. Hei 11-279657

[0021] Patent Document 6

[0022] Japanese Patent Application Laid-open No. Hei 11-293345

[0023] Patent Document 7  
[0024] Japanese Patent Application Laid-open No. 2003-94104  
[0025] Patent Document 8  
[0026] Japanese Patent No. 06079660  
5 [0027] Patent Document 9  
[0028] Japanese Patent No. 07003279  
[0029] Non-patent Document 1  
[0030] "Theory and Practice of Plate Rolling" p.218, The Iron  
and Steel Institute of Japan

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#### Summary of the Invention

[0031] It is an objectone of the objects of the present invention to provide a safe and stable lubricated hot rolling method not causing any fire accident, when a lubricating oil 15 which is added with one kind or two or more kinds among high-basic alkaline-earth metal phenate, high-basic alkaline-earth metal carboxylate, high-basic alkaline-earth metal salicylate, high-basic alkaline-earth metal sulfonate, and the like, is supplied by a, e.g., the gas atomizing method.

20 [0032] After dedicated examinations to solve the problems, the inventor discovered that According to one exemplary embodiment of the present invention, it is possible to perform a safe and stable lubricated hot rolling while preventing fire from occurring even if a lubricating oil is supplied by the gas

atomizing method in which the ~~aforesaid~~ high-basic alkaline-earth metal compound of relatively high viscosity is blended, with the following exemplary conditions:

5 (1i) the average particulate size of the lubricating oil is made to be less than 1 mm,

(2ii) the flow rate of the noncombustible gas (for example, air, helium, nitrogen, argon, or the like) sprayed concurrently with the lubricating oil in a form of particulates is made to be 2000 cm<sup>3</sup> or more per minute,

10 (3iii) the spraying speed of the gas is made to be 1 m or more per second, and

(4) the maximum amount of lubrication supply is made to be 20 cm<sup>3</sup> or less per 1 m<sup>2</sup> of the roll surface area.  
15 iv) the maximum amount of lubrication supply is made to be 20 cm<sup>3</sup> or less per 1 m<sup>2</sup> of the roll surface area.

[0033] For example, in order to prevent fire caused by the lubricating oil, scattering of the lubricating oil sprayed from the nozzle to areas other than the rolls should be prevented as much as possible, and 100% of the lubricating oil sprayed from the nozzle should adhere to the roll surface. This can be because that when the lubricating oil adherent to the roll surface is guided into the roll bite, the atmospheric gas is blocked so that the lubricating oil is carbonated while producing the lubricating effect without flaming up. The roll

bite represents a region in a clearance between two rolls at which the rolls are directly in contact with a material to be rolled. However, in actual instances, it may be difficult for 5 100% of the lubricating oil sprayed from the nozzle to adhere to the roll surface. Indeed, some of the lubricating oil may adhere to the incidental facilities of the rolling mill provided around the rolls, for example, a water-drying wiper for the roll cooling water, roll-chock, inside of the housing of the rolling mill, guide, table roller, and so forth, because of the external 10 elements such as the usage environment, in addition to the supplying method or supplying conditions of the lubricating oil.

[0034] In order to prevent fire caused by the lubricating oil, for example, scattering of the lubricating oil sprayed from the nozzle to areas other than the rolls should be 15 prevented as much as possible, and 100% of the lubricating oil sprayed from the nozzle should adhere to the roll surface. This is because that when the lubricating oil adherent to the roll surface is guided into the roll bite, the atmospheric gas is blocked so that the lubricating oil is carbonated while 20 producing the lubricating effect without flaming up. The roll bite represents a region in a clearance between two rolls at which the rolls are directly in contact with a material to be rolled. However, in actual instances, it is impossible that 100% of the lubricating oil sprayed from the nozzle adheres to

the roll surface, and some of the lubricating oil adheres to the incidental facilities of the rolling mill provided around the rolls, for example, a water drying wiper for the roll cooling water, roll check, inside of the housing of the rolling mill, 5 guide, table roller, and so forth, because of the external elements such as the usage environment, in addition to the supplying method or supplying conditions of the lubricating oil. The lubricating oil adherent to the facilities around the rolls ~~is~~ can be deposited with increment of the lubrication supply 10 time, and may form oil spots which drop to or are deposited on the plate path, or drop to the hot rolled steel which is in course of being rolled, causing fire. Further, from the surface of the steel being rolled, a high-temperature matter such as a scale may peel off and reach the lubricating oil adherent to and 15 deposited on an incidental facilities of the rolling mill, generating a flame to cause fire. However, ~~normally~~, a large amount of roll cooling water ~~is~~ may be generally supplied to the rolls, so that the water spots scatter to the facilities around the rolling mill as well. Accordingly, if a flame caused is to 20 some extent small, any fire caused thereby ~~is~~ can be extinguished without spreading. In addition, when an emulsified lubricant is used, water is sprayed with the lubricating oil concurrently, so that the concern about causing a fire accident does not exist unless the concentration of the lubricating oil is 70% by weight

or more. On the other hand, when the lubricating oil is supplied by a gas atomizing method, such an effect cannot be expected, so that ~~some sort of a particular measure comes to~~<sup>may</sup> be necessary preferable.

5 [0035] In ~~lightview~~ of the fire-accident-causing elements described ~~in the preceding paragraph~~<sup>above</sup>, the points to prevent fire accident ~~are~~can be:

- —attaching the lubricating oil sprayed from the nozzle to the surface of the rolls as much as possible;
- —taking such measures that does not easily cause igniting even if the lubricating oil adheres to a facility other than the rolls; and/or
- —not allowing the lubricating oil sprayed from the nozzle to ignite while it reaches the rolls. The conditions in order to realize these points in the gas atomizing supply method are:

[0036] The conditions in order to realize these points in the gas atomizing supply method may be:

- (1) the average particulate size of the lubricating oil is made to be less than 1 mm;
- (2) the flow rate of the noncombustible gas (for example, air, helium, nitrogen, argon, or the like) sprayed concurrently with the lubricating oil in a form of particulates is made to be 2000 cm<sup>3</sup> or more per minute;

(3iii) the spraying speed of the gas is made to be 1 m or higher per second; and/or

(4iv) the maximum amount of lubrication supply is made to be 20 cm<sup>3</sup> or less per 1 m<sup>2</sup> of the roll surface area.

5 100371 The lubricating oil ~~is~~can be granulated into particulates having a size less than 1 mm, because lightening the weight of the lubricating oil drop allows most of the lubricating oil sprayed from the nozzle to reach the rolls by the airflow of the noncombustible gas. If a lubricating oil 10 whose particulates have a size of 1 mm or more is sprayed, the lubricating oil, particularly that sprayed from the lubricating nozzle for the upper roll, ~~comes to be~~may become easily droppable to the steel material, igniting by the heat of the steel material, and leading to likelihood of flashing of the oil 15 adherent to the surface of the facilities provided near an edge portion of the steel material. If the particulate size is less than 1 mm, e.g., virtually no lubricating oil drops from the nozzle, and even if it ignites, its volume is ~~so~~ small enough that it immediately burns out, and does not spread to other 20 parts. ~~Incidentally, if the average particulate size is more than 5 mm, the lubricating oil adherent to the rolls becomes easily droppable because of its own weight. Further, the lubricating oil adherent to the rolls tends to spread in the direction of the length of the roll before guided to the roll~~

bite, much of which extends along the surface of the rolls other than the plate path and drops down, so that likelihood of ignition becomes high. The method of granulating the lubricating oil to particulates can be any method. For example, 5 it may be in a spraying method, or a method in which a mesh is passed through to make particulates. In addition, supplying by granulating or atomizing the lubricating oil into particulates secures supplying of a smaller amount in a spraying manner. It is preferable to supply the lubricating oil by granulating or 10 atomizing it into a size of 0.05 mm to less than 1 mm.

[0038] If the average particulate size is more than 5 mm, the lubricating oil adherent to the rolls becomes easily droppable because of its own weight. Further, the lubricating oil adherent to the rolls tends to spread in the direction of the 15 length of the roll before guided to the roll bite, much of which extends along the surface of the rolls other than the plate path and drops down, so that likelihood of ignition becomes high. The method of granulating the lubricating oil to particulates can be any method, e.g., a spraying method, or a method in which 20 a mesh is passed through to make particulates. In addition, supplying by granulating or atomizing the lubricating oil into particulates secures supplying of a smaller amount in a spraying manner. It may be preferable to supply the lubricating oil by

granulating or atomizing it into a size of 0.05 mm to less than 1 mm.

100391 The For example, the flow rate of the noncombustible gas sprayed concurrently with the lubricating oil is can be set 5 to 2000  $\text{cm}^3$  or greater per minute because the high gas flow rate creates a shield of the noncombustible gas around a particulate of the lubricating oil, so that ignition before the sprayed lubricating oil adheres to the rolls does not easily occur. Further, should if the sprayed lubricating oil flushflushes off 10 around the rolls, a supply of a large amount of noncombustible gas createscan create gas flows around the surface of the rolls and the circumference thereof, so that there is an effect of blowing off a flame caused near the rolls. A flow rate of the noncombustible gas of less than 2000  $\text{cm}^3$  per minute is 15 insufficient to attain such an effect. Incidentally, unless a noncombustible gas of 1000  $\text{cm}^3$  or more per minute is sprayed, it is can be difficult to eliminateremove a normally assumed amount of water film present over the surface of the rolls and attach the lubricating oil to the rolls.

20 100401 By making the flow velocity of the noncombustible gas 1 m or higher per second, the speed of the lubricating oil sprayed from the nozzle is made high, and the time from spraying the lubricating oil out of the nozzle up to reaching thereof to the rolls is can be shortened. This substantially enhances the

effect of preventing the sprayed lubricating oil from scattering to somewhere other than the roll surface. ~~Just~~By increasing the flow rate while leaving the flow velocity to less than 1 m per second encourages ~~all the more the~~additional scattering of the lubricating oil in the form of particulates to somewhere other than the rolls. Unless both the flow rate and flow velocity are appropriately set out, the phenomenon that the lubricating oil scatters and is deposited on facilities other than the roll surface ~~comes to be likely to~~may occur frequently. In addition, if the gas flow velocity is higher, the effect of blowing out the flame which has ignited near the rolls is ~~all the more~~can be enhanced. Both the gas flow rate and the gas flow velocity being made high ~~is~~can be very effective in preventing the flame from being created and in extinguishing a flame caused, and forms an important element of the present invention.

[0041] If the maximum amount supplied of the lubricating oil exceeds 20 cm<sup>3</sup> per 1 m<sup>2</sup> of the area of the roll surface, the lubricating effect is improved, but the supply becomes excessive, and in some instances leads to the lubricating oil spilling out of the plate path, blown out of the rolls with the centrifugal force by the rolling of the rolls, and scattering to and being deposited on the facilities around the rolls. This ~~turns into~~can become the origin of the fire, leading to higher probability of occurrence of fire accident. In the amount of 20

cm<sup>3</sup> or less, most of the lubricating oil sprayed to the rolls is guided into the roll bite, consumed by the friction between the rolls and the steel material, so that it does not turn into the origin of the fire. In addition, with an amount of the 5 lubricating oil of 0.01 cm<sup>3</sup> or more per 1 m<sup>2</sup>, a bit slippage can be prevented. Further, if the amount supplied of the lubricating oil is more than 30 cm<sup>3</sup> per 1 m<sup>2</sup> of the roll surface area, the rolling slippage occurs under any rolling condition, so that the amount supplied should be that volume or less. 10 ~~Needless to say~~Thus, an amount supplied exceeding 30 cm<sup>3</sup> per 1 m<sup>2</sup> of the roll surface area ~~causes~~can cause a fire accident, and it ~~is impossible~~may be difficult to safely perform hot rolling. If the operation is performed preferably with the amount of the lubricating oil to be supplied being in a range of 0.1 cm<sup>3</sup> to 15 15 cm<sup>3</sup> per 1 m<sup>2</sup> of the roll surface area, it ~~is~~may be effective from the aspect of lubricity, economical efficiency, and safety.

[0042] According to an exemplary embodiment of the present invention, when a lubricating oil being added with one kind or two or more kinds among the high-basic alkaline-earth 20 metal phenate, high-basic alkaline-earth metal carboxylate, high-basic alkaline-earth salicylate, or high-basic alkaline-earth metal sulfonate is supplied by the gas atomizing method to perform lubricated rolling, it generally does not cause bit slippage, rolling slippage, and the like, while a lubricating

effect of the same or higher level compared to conventional lubrication supply methods can be brought out, and at the same time a safe and stable lubricated rolling can be performed without causing fire.

5 [0043] These and other objects, features and advantages of the present invention will become apparent upon reading the following detailed description of embodiments of the invention, when taken in conjunction with the appended claims..

10 **Brief Description of the Drawings**

[0044] Further objects, features and advantages of the invention will become apparent from the following detailed description taken in conjunction with the accompanying figure showing illustrative embodiments, results and/or features of the 15 exemplary embodiment(s) of the present invention, in which:

[0045] Fig.1 is a chart showing a illustrating an exemplary correlation of a marginal level of slippage occurrence and a range of occurrence of fire caused by a lubricating oil, with an amount supplied of the lubricating oil;

20 [0046] Fig. 2 is a chart showing a illustrating an exemplary correlation between the range of occurrence of fire caused by a lubricating oil and flow rates of a noncombustible gas;

[0047] Fig. 3 is a chart showing aillustrating an exemplary correlation between the range of occurrence of fire caused by a lubricating oil and flow velocities of a noncombustible gas; and

5 [0048] Fig. 4 is a chart showing aillustrating an exemplary correlation between the range of occurrence of fire caused by a lubricating oil and average sizes of particulates of the lubricating oil.

10

### Detailed Description of the Preferred Embodiments

[0049] Examples of embodiments of a lubricated hot rolling according to the present invention will be explained. Exemplary embodiments of a lubricated hot rolling according to the present invention are described below.

[0050] For example, a lubricating oil which contains 15 vol% of calcium sulfonate having a basicity of 300 mgKOH/g and has a viscosity at 40°C of 170 cSt can be prepared. As a lubricating oil supplying nozzle, an air-atomizing nozzle is used, and the lubricating oil and a noncombustible gas are supplied to the rolls in a manner the both are sprayed in a common nozzle. Needless to say, the lubricating oil and the noncombustible gas may be supplied in a manner of being sprayed from separate nozzles. Before a material is bit into a particular rolling mill, the lubricating oil is sprayed to the rolls, with the amount of lubricating oil supplied of 0.7 cm<sup>3</sup> or less per 1 m<sup>2</sup> of the roll surface area per nozzle, under such conditions that a nitrogen gas as the noncombustible gas has a gas flow rate of 2200 cm<sup>3</sup> per minute and a gas flow velocity of 2.5 m/sec and that an average size of particulates of the lubricating oil is 0.8 mm, by a gas atomizing supply method. After the steel material to be rolled is bit into the rolling mill, a nitrogen gas in the amount of 3000 cm<sup>3</sup> per minute is sprayed at a flow velocity of 3 m per second, and the above-described lubricating oil is

continuously supplied to the rolls with the particulate size thereof remaining the same, by the gas atomizing method.

[0051] A lubricating oil which contains 15 vol% of calcium sulfonate having a basicity of 300 mgKOH/g and has a viscosity at 40°C of 170 cSt is prepared. As a lubricating oil supplying nozzle, an air atomizing nozzle is used, and the lubricating oil and a noncombustible gas are supplied to the rolls in a manner the both are sprayed in a common nozzle. Needless to say, the lubricating oil and the noncombustible gas may be supplied in a manner of being sprayed from separate nozzles. Before a material is bit into a particular rolling mill, the lubricating oil is sprayed to the rolls, with the amount of lubricating oil supplied of 0.7 cm<sup>3</sup> or less per 1 m<sup>2</sup> of the roll surface area per nozzle, under such conditions that a nitrogen gas as the noncombustible gas has a gas flow rate of 2200 cm<sup>3</sup> per minute and a gas flow velocity of 2.5 m/sec and that an average size of particulates of the lubricating oil is 0.8 mm, by a gas atomizing supply method. After the steel material to be rolled is bit into the rolling mill, a nitrogen gas in the amount of 3000 cm<sup>3</sup> per minute is sprayed at a flow velocity of 3 m per second, and the above-described lubricating oil is continuously supplied to the rolls with the particulate size thereof remaining the same, by the gas atomizing method. Depending on changes in the rolling speed, the rolling is

performed by adjusting the amount of the lubricating oil supplied in a spraying manner to be  $0.01 \text{ cm}^3$  to  $20 \text{ cm}^3$  or less for  $1 \text{ m}^2$  of the roll surface area. ~~Here~~Thus, ~~so~~as long as the amount supplied of the lubricating oil is  $0.01 \text{ cm}^3$  to  $20 \text{ cm}^3$  or less per  $1 \text{ m}^2$  of the roll surface, based on an assumption that controlling is performed within that range, the rolling can be performed while adjustment is made in a manner that the rolling load and friction coefficient remain constant. Unless the amount supplied of the lubricating oil is increased according to the rolling speed increment, the lubricant oil goes short so that an expected lubricating effect may not be attained. Further, if the amount supplied of the lubricating oil exceeds  $20 \text{ cm}^3$  per  $1 \text{ m}^2$  of the roll surface area, a trouble such as breaking of fire occurs, so that the amount supplied of the lubricating oil should be kept within the range between  $0.01 \text{ cm}^3$  to  $20 \text{ cm}^3$  or less per  $1 \text{ m}^2$  of the roll surface area. Thereafter, the lubrication supply is continued until immediately before the material passes through the rolling mill. When the material is completing passing through the rolling mill, the amount supplied of the lubricating oil is preferably set to  $1 \text{ cm}^3$  or less per  $1 \text{ m}^2$  of the roll surface area when the length of the material to be rolled becomes around five times of the peripheral length of the roll. ~~By doing so~~In this manner, biting (e.g., passing through)

of a following material is smoothed and the bit slippage is not caused.

— First Embodiment —

5 **FIRST EXEMPLARY EMBODIMENT**

[0052] The inventor of the present invention investigates ~~a~~ controlling effect of generation of a mill scale of rolls according to the present invention is reviewed, and and a determination is made as to whether flashing phenomenon occurs 10 or not during experiments, e.g., by using a hot rolling friction testing machine.

<Experimental Conditions>

Experimental piece: diameter 80 mm, width 10 mm,

15 made of an HSS roll material

Counterpart piece: diameter 165 mm, width 15 mm,  
made of S45C

Load: 30 kgf

Rotational speed of experimental piece: 176 m/min

20 Speed of counterpart piece: 185 m/min

Temperature of friction surface of experimental piece:  $650^{\circ}\text{C}$

Temperature of friction surface of counterpart piece:  $880^{\circ}\text{C}$

25 Exemplary Lubricating oil:

(a) A lubricating oil in which 15 vol% of calcium sulfonate having a basicity of 300 mgKOH/g is blended in a mineral oil, and whose viscosity at  $40^{\circ}\text{C}$  is 110 cSt.

(b) A lubricating oil in which 15 vol% of a colza oil is blended in a mineral oil and whose viscosity at  $40^{\circ}\text{C}$  is 112 cSt (prepared for comparison).

Exemplary Supply methodMethod:

(i) A gas atomizing method. The amount supplied wascan be approximately  $3 \text{ cm}^3/\text{m}^2$ , and used as gas was nitrogen. The gas flow rate wascan be provided in two levels which weremay be  $1000 \text{ cm}^3/\text{min}$  and  $2500 \text{ cm}^3/\text{min}$ , and an average particulate size of the lubricating oil was approximately 200 micron. The flow velocity wasmay be 3 m per second.

(ii) Supplied as a 0.8% emulsion (the lubricating oil content is supplied at  $3.2 \text{ cm}^3/\text{m}^2$ ).

Rolling friction time period: 10 minutes

<Experimental Result>

Lubricating oil "(a)" and supply method "(i)" (a flow rate of  $1000 \text{ cm}^3/\text{min}$ )

→ Thickness of the mill scale: 2  $\mu\text{m}$  or less, ignition occurred at a part of the experimental piece.

Lubricating oil "(a)" and supply method "(i)" (a flow rate of 2500 cm<sup>3</sup>/min)

→ Thickness of the mill scale: 2 µm or less, no ignition occurred.

5 Lubricating oil "(a)" and supply method "(ii)" →  
Thickness of the mill scale: about 3 µm, no ignition phenomenon occurred.

Lubricating oil "(b)" and supply method "(i)" (a flow rate of 1000 cm<sup>3</sup>/min)

10 → Thickness of the mill scale: about 8 µm, an ignition phenomenon occurred.—

Lubricating oil "(b)" and supply method "(i)" (a flow rate of 2500 cm<sup>3</sup>/min)

→ Thickness of the mill scale: about 8 µm, no ignition phenomenon occurred.

15 Lubricating oil "(b)" and supply method "(ii)" →  
Thickness of the mill scale: about 9 µm, no ignition phenomenon occurred.

[00531] When the lubricated rolling method according to the exemplary embodiment of the present invention is used, the 20 thickness of the mill scale formed on the surface of the experimental piece made of an HSS roll material was 2 µm or less, and further, fire did not occur around the experimental piece or a lubricant supply section during the experiment. However, in

the same gas atomizing supply method, under the condition of a lower flow rate of the noncombustible gas, an ignition phenomenon by deposition of the lubricating oil on a part of the counterpart piece steel material was observed. This is thought 5 to occur~~may~~ because the shielding effect and blowing-off effect by the noncombustible gas were not sufficient. Since the thickness of the mill scale is approximately 3  $\mu\text{m}$  when the same lubricating oil was supplied by the conventional water injection method, it is verified that the lubricating effect of the same 10 level as with the conventional method or higher could be attained by the present invention, and it was confirmed that the conditions under which fire does not occur when the lubricating oil is directly supplied can be formed.

【0054】 ~~Second Embodiment~~

15

SECOND EXEMPLARY EMBODIMENT

【0055】 ~~The inventor of the present invention used~~ It is possible to use a 2Hi rolling mill (2-high mill) to examine a lowering effect of friction coefficient serving as a 20 representative indicator of the lubricating performance when the lubricating-oil-supplying conditions were changed, and at the same time examined, by a rolling experiment, a marginal condition of occurrence of ignition. In this exemplary experiment, base conditions in accordance with the exemplary

embodiment of the present invention with respect to four kinds of supply conditions were provided, and on the basis thereof, a lowering effect of the friction coefficient and occurrence of an ignition phenomenon were investigated by changing each condition 5 of the four kinds of conditions separately.

<Experimental Conditions>

Roll: diameter 400 mm, HSS roll, roll length 100 mm

10 Material to be rolled: 0.02% carbon steel, thickness 1 mm × width 50 mm × length 1000 m (coil)

Heating temperature: 1000°C (nitrogen atmosphere)

Rolling speed: 50 m/min

Roll gap: 20% to 40% in terms of draft ratio

15 Lubricating oil: a lubricating oil in which 25 vol% of calcium sulfonate having a basicity of 300 mgKOH/g is blended in a mineral oil, and whose viscosity at 40°C is 110 cSt.

Supply conditions: supply by a spray nozzle.

20 Used as the noncombustible gas was nitrogen.

(a) Amount supplied: 0.05 to 30 cm<sup>3</sup>/m<sup>2</sup> (base condition: 2.5 cm<sup>3</sup>/m<sup>2</sup>)

(b) Flow rate of gas: 200 cm<sup>3</sup>/min to 10000 cm<sup>3</sup>/min (base condition: 3000 cm<sup>3</sup>/min)

(c) Flow velocity of gas: 0.2 m per second to 10 m per second (base condition: 2 m per second)

    (d) Average size of particulates of lubricating oil: 0.02 mm to 3 mm (base condition: 0.8 mm)

5       <Experiment Result>

[0056]       A rolling experiment was performed by varying the supply condition "(a)" while the conditions "(b)", "(c)", and "(d)" equaled the respective base conditions thereof. Fig. 1 shows a friction coefficient lowering effect and a range of 10 occurrence of the ignition phenomena during the experiment, when the amount supplied of the lubricating oil was changed. As shown in Fig. 1, the ignition of the supplied lubricating oil was observed when the amount supplied exceeded  $20 \text{ cm}^3/\text{m}^2$ , but within the range of the conditions of the present invention, the 15 supplied lubricating oil did not ignite by being rolled while lubrication was supplied during the hot rolling, and rolling was performed without causing a slippage accident. The amount supplied of  $30 \text{ cm}^3/\text{m}^2$  or more caused a rolling slippage, in which case rolling could not be performed. It was also confirmed that 20 the lubricating effect of at least the same level as conventionally obtained or higher could be obtained.

[0057]       A continuous hot rolling of approximately 20 minutes was performed, by changing the flow rate of the gas in the supply condition "b" while the remaining supply conditions

equaled the respective base conditions thereof. Fig. 2 shows a friction coefficient lowering effect and a range of the occurrence of the ignition phenomena during the experiment, when the amount supplied of the noncombustible gas (a nitrogen gas in 5 this instance) was changed. As shown in Fig. 2, a lubricating effect was exerted with the gas flow rate of 1000 cm<sup>3</sup>/min or higher, while it was observed that the supplied lubricating oil with a gas flow rate of less than 2000 cm<sup>3</sup>/min caused an ignition phenomenon. Accordingly, the gas flow rate should be set to 10 2000 cm<sup>3</sup> or higher per minute in order to bring out the lubricating effect while preventing the ignition of the lubricating oil. It was also confirmed that a lubricating effect of at least the same level as conventionally attained or higher could be obtained.

15 100581 A rolling experiment was performed by changing the gas flow velocity of the supply condition "(c)", while the remaining supply conditions equaled base conditions each thereof. Fig. 3 shows a friction coefficient lowering effect and a range of occurrence of ignition phenomena during the 20 experiment when the gas flow velocity was changed. As shown in Fig. 3, when the gas flow velocity was less than 1 m/sec, phenomena of ignition of the lubricating oil were frequently observed during the lubricated rolling. However, supplying by setting the gas flow velocity to 1 m/sec or higher allowed the

lubricated rolling without causing the ignition of the lubricating oil. It was also observed that the lubricating effect of at least the same level as conventionally attained or higher could be obtained.

5 100591 A rolling experiment was performed by changing the average size of particulates of the lubricating oil in the supply condition "(d)". Fig. 4 shows a friction coefficient lowering effect and a range of occurrence of ignition phenomena during the experiment when the average particulate size of the 10 lubricating oil was changed. As shown in Fig. 4, when the average particulate size was 1 mm or larger, occasional ignitions were observed during the lubricated rolling. However, when the average particulate size was made below 1 mm, no ignition phenomena were observed in performing lubricated 15 rolling. It was also confirmed that the lubricating effect of at least the same level as conventionally attained or higher could be obtained.

### Industrial Applicability

[0060] According to the present invention, if a lubricating oil being added with one kind or two or more kinds among the high-basic alkaline-earth metal phenate, high-basic 5 alkaline-earth metal carboxylate, high-basic alkaline-earth salicylate, or high-basic alkaline-earth metal sulfonate is supplied by a gas atomizing method to perform lubricated rolling, it does not cause bit slippage, rolling slippage, and the like. Further, a lubricating effect of at least the same or 10 higher level compared to conventional lubrication supply methods can be brought out. Furthermore, a safe and stable lubricated rolling can be performed without causing fire.

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